RT1 Thermodynamics

1. Boyle's Law

$$\boxed{PV = constant}$$

2. Ideal Gas Law and Boltzmann's Law

$$\boxed{PV = nRT}$$

$$\boxed{PV = nkT}$$

3. Average Molecular Kinetic Energy

$$\boxed{E_k = \frac{3}{2}kT}$$

4. Internal Energy Including Temperature

$$\boxed{\triangle U = \frac{3}{2}nR\triangle T}$$

5. First Law of Thermodynamics

$$\boxed{\triangle U = W + Q}$$

6. Heat in an Isochoric Process

$$\boxed{Q = \triangle U}$$

7. Work Done by an Ideal Gas

$$\boxed{W = P\triangle V}$$

8. Work in an Isochoric Process

$$\boxed{W = 0}$$

9. Heat Required to Raise the Temperature of a Substance

$$\boxed{Q = mc\triangle T}$$

10. Average Speed of a Gas Molecule

$$\boxed{v_{rms} = \sqrt{\frac{3RT}{M}}}$$

11. Mechanical Equivalent of Heat

$$\boxed{Q = W}$$

12. If the volume of a gas is doubled and the pressure is tripled, what happens to the average velocity of the gas particles?

$$(2V)(3P) = nR(6T)$$

$$xv_1 = \sqrt{\frac{3RT}{M}} = v_2 = \sqrt{\frac{3R(6T)}{M}}$$

$$x = \boxed{\sqrt{6}}$$

1. A 0.45kg sample of substance at 398K is placed into a container containing 0.1kg of water at 283K. The resulting temperature is 298K. What is the specific heat of the substance?

$$m_1 c_1 \triangle T_1 = m_2 c_2 \triangle T_2$$

$$0.45kg(c_1)(100K) = 0.1kg(4186J/kg/K)(15K)$$

$$c_1 = \boxed{140J/K/kg}$$

2. A 250 liter electric hot water heater is rated at 4 kW of power. Assuming no heat loss how long will it take to heat water from 303K to 318K?

$$mc\triangle T = 250kg(4186J/kg/K)(15K) = 15700kJ$$

$$\frac{15700kJ}{4kW} = \boxed{3930s}$$

3. If an average molecule of "Substance Q" is moving at 800 m/s when the temperature is 553K, what is the mass of one molecule of "Substance Q" in atomic mass units?

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$$800m/s = \sqrt{\frac{3(8.315J/mol/K)(553K)}{M}}$$

$$M = 0.0216kg/mol = 21.6g/mol$$

Thus, one molecule has a mass of $\boxed{21.6amu}$

4. A heat engine does 7200 J of work in each cycle while absorbing 58600J of heat from a high temperature reservoir. What is the efficiency of this engine?

$$\eta = \frac{|\sum W|}{Q_{in}} = \frac{7200J}{58600J} = 0.123 = \boxed{12.3\%}$$

5. The exhaust temperature of a heat engine is 693K. What must be temperature of the high temperature reservoir if the Carnot efficiency is to be 38 percent?

$$\eta_{Carnot} = 1 - \frac{T_{min}}{T_{max}}$$

$$0.38 = 1 - \frac{693K}{T_{max}}$$

$$T_{max} = \boxed{1120K}$$

6. A Carnot engine performs work at the rate of 620 Watts while using 780 Joules of heat per second. If the temperature of the heat source is 1400 Kelvin, at what temperature is the waste heat exhausted?

$$\eta_{Carnot} = \eta$$

$$1 - \frac{T_{min}}{1400K} = \frac{620J/s}{780J/s} = 0.795$$

$$\frac{T_{min}}{1400K} = 0.205$$

$$T_{min} = \boxed{287K}$$

1. One mole of ideal monatomic gas, initially at point A at a pressure of 100.0 E3 Newtons per meter squared and a volume of 25.0 E-3 meter cubed, is taken through a 4-process cycle. Cv = (3/2)R and Cp = (5/2)R where R = 8.31 J/(mol/K).

$$\triangle U = \frac{3}{2}n(8.315J/mol/K)(\triangle T)$$

$$W = P\triangle V$$

$$Q = \triangle U - W$$

$$T = \frac{PV}{nR} = \frac{PV}{1mol(8.315J/mol/K)}$$

$$T_A = 300K$$

$$T_B = 1,800K$$

$$T_C = 2,700K$$

$$T_D = 1,200K$$

AB

$$\triangle U = \frac{3}{2}1mol(8.315J/mol/K)(1,500K) = \boxed{18,700J}$$

$$W = \frac{1}{2}(0.025m^3)(200,000Pa) + (0.025m^3)(100,000Pa) = \boxed{-5,000J}$$

$$Q = \boxed{23,700J}$$

BC

$$\triangle U = \frac{3}{2}1mol(8.315J/mol/K)(900K) = \boxed{11,200J}$$

$$W = (0.025m^3)(300,000Pa) = \boxed{-7,500J}$$

$$Q = \boxed{18,700J}$$

CD

$$\triangle U = \frac{3}{2}1mol(8.315J/mol/K)(1,500K) = \boxed{-18,700J}$$

$$W = \frac{1}{2}(0.025m^3)(200,000Pa) + (0.025m^3)(100,000Pa) = \boxed{-5,000J}$$

$$Q = \boxed{-13,700J}$$

DA

$$\triangle U = \frac{3}{2}1mol(8.315J/mol/K)(900K) = \boxed{-11,200J}$$

$W = (0.075m^3)(100,000Pa) = \boxed{7,500J}$

$Q = \boxed{-18,700J}$

ABCDA

$\triangle U = \sum \triangle U = \boxed{0J}$

$W = \sum W = \boxed{-10,000J}$

$Q = \sum Q = \boxed{10,000J}$

2. What is the net work done in the cyclic process ABCDA?

$\sum W = (-5,000J) + (-7,500J) + (-5,000J) + (7,500J) = \boxed{-10,000J}$

3. What is the maximum theoretical efficiency of the process?

$$\eta_{Carnot} = 1 - \frac{T_{min}}{T_{max}} = 1 - \frac{300K}{2700K} = 0.888 = \boxed{88.9\%}$$

4. What was the actual efficiency of the process?

$$\eta = \frac{|\sum W|}{Q_{in}} = \frac{10,000J}{42,400J} = 0.236 = \boxed{23.6\%}$$

5. For an ideal gas, each of the following unquestionably leads to an increase in the pressure of the gas, except one. Which one is it?

$\boxed{B}$ Increasing the temperature, the volume and the number of moles of the gas does not necessarily do so.

6. The pressure of a monatomic ideal gas is doubled, while the volume is cut in half. By what factor is the internal energy of the gas multiplied?

$\boxed{C}$ It remains the same, as temperature doesn't change because $(\frac{1}{2}V)(2P) = VP$